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ORGANIC CARBON AND NITROGEN CONTENT OF SOIL ALONG SLOPE POSITIONS UNDER RUBBER PLANTATION OF VARYING AGES IN ODIGBO LGA OF ONDO STATE

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ABSTRACT

Relief has a strong influence on soil development and soil along a slope has been noticed to vary in both physical and chemical properties. Slope position influences soil properties because of erosional and depositional processes. The study examines the organic carbon and nitrogen content of soil under rubber plantation of varying ages as influenced by slope positions in Ondo state. Soil samples were taken at the depth of 0-15cm along four different transects considering different slope positions (upper, middle and lower). The rubber plantations were of ages 6, 15 and 22. The sampled soils were analyzed considering their particle size distribution, organic carbon and nitrogen content. Results of the finding were statistically analyzed using ANOVA. It was revealed that there are differences in the content of organic carbon and nitrogen along the slope positions. Soil organic carbon and nitrogen content were highest at the lower slope positions which were attributed to the effect of relief, the upper slope positions had lower content due to the impact of erosion likewise the middle slope positions of the rubber plantations. With increase in age of rubber at the upper slope positions, organic carbon and nitrogen content reduced. However, it was recommended that management practices such as terracing and land leveling should be employed to reduce the impact of relief on soil properties, fertilizer application should be based on the different slope positions and proper soil survey should be done before any agricultural practice takes place on sloping areas to ascertain the suitability of such areas for plantation.

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1.0 INTRODUCTION

Variation in the environment gives rise to variation in soils since both the direction and the rate of the processes responsible for soil development are controlled by the environment. Various factors (i.e., climate, parent material, organism, topography, and time) influence soil development and understanding the effects of these factors on soil properties is vital for modeling soil landscape relationship and establishing sustainable, on-site management practices. McFadden and Knuepfer (1990) observed that soil development is intimately linked to landscape evolution and at the landscape scale, topography is one of the main factors controlling soil processes, as it influences the intensity of several processes such as erosion, sediment redistribution, and local drainage (by local slope or curvatures). Its geometry, such as slope angle and length influence runoff, drainage and soil erosion causing a significant difference in soil physico-chemical properties (Brubaker, Jones, Lewis & Frank 1993). Soils along a hill slope usually exhibit prominent differences in morphology that may be attributed to the influence of moisture status, microclimate, and vegetation (Birkeland, 1999). The topography of an area affects the microclimate, soil formation, parent material, hydrological and geological processes which in turn affect soil processes, (Rasool et al, 2014) and this can lead to variations in the physical and chemical properties of soils depending on the soils position in the local topography. This in turn affects the growth condition of plants in different slope position based on the bioavailability of soil nutrients and on the other hand, the nutrients in falling litter from plants can return to the soils through microbial decomposition, soil mineralization and nutrient cycling in the forest ecosystem. Such recycling processes also determine the spatial variation of soil nutrients in the forest ecosystem. In essence, topography affects the pattern of soil distribution over landscape even when the soils are derived from the same parent material (Esu, Akpan-Idiok & Eyong, 2008; Jimoh, Yau & Essoka 2020).

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Soil is an important natural resource for growing plants, food, and fibre. The suitability of soil for crop production is based on the quality of the physical, chemical, and biological properties of the soil, which if properly managed and conserved, will help in protecting the environment and help in identifying sustainable ecological practice to improve soil fertility.

Understanding the part played by topography will assist in developing strategies for soil conservation and help in assessing productive values of soils.

1.1 AIM AND OBJECTIVES

The aim of the study is to examine the effect of slope positions on organic carbon and nitrogen content under rubber plantations of different ages.

The specific objectives are to:

i. Examine the soil particle size distribution, the organic carbon and nitrogen content in the upper. middle and lower positions of the slope under rubber plantation of varying ages.

ii. Examine the effects of slope position on the organic carbon of soil under rubber plantation of varying ages.

iii. Examine the effects of slope position on the nitrogen content of soil under rubber plantation of varying ages.

2.0 MATERIAL AND METHOD

Study Area

The study area is the Rubber Estate Nigeria limited in the Western part of Nigeria. It is located between Latitudes 6º37' and 7º20' and Longitude 4º27'E and 5º5'E. It is in Odigbo local government of Ondo state. The area generally falls within the Western upland region of Nigeria (Udo, 1982) and it is a transition between basement complex and sedimentary rocks. Much of it lies between 200 and 300 meters above sea level. The study area is composed of lowlands and rugged hills with granitic outcrops in some places. The climate is characterized by distinct wet and dry seasons with mean monthly temperature of 27ºC with a maximum range of 7^0C. The coldest month is June while the hottest are February and March when it may be as high as 34ºC. The climate of the study area is characterized by high temperature and rainfall. The pattern of rainfall is characterized by the double maxima regime, the two periods of maximum rainfall being June/July and September/October. The natural vegetation of the area is the evergreen lowland tropical

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rain forest, which is a mixture of both deciduous and evergreen plants. It is rich in biodiversity. The forest has a high density of various tree species. As a result of human interference, the original vegetation has been degraded to secondary forests while hundreds of square kilometers are covered by rubber plants (*Hevea brasiliensis*) and perennial plants like *Theobroma cacao*, *Elaeis guineensis* and other food crops. The soil is well aerated and drained, with relatively low capillarity. It is highly dynamic along slopes but very stable, old and deep on the plain and undulating terrain. The soil is deep and well drained and considered to be highly suitable for cultivating rubber. The study area is majorly characterised by agricultural practices. The soils belong to the *Ondo* series `classified as O*xic Paleustalfs* Nwachokor and Uzu (2008),

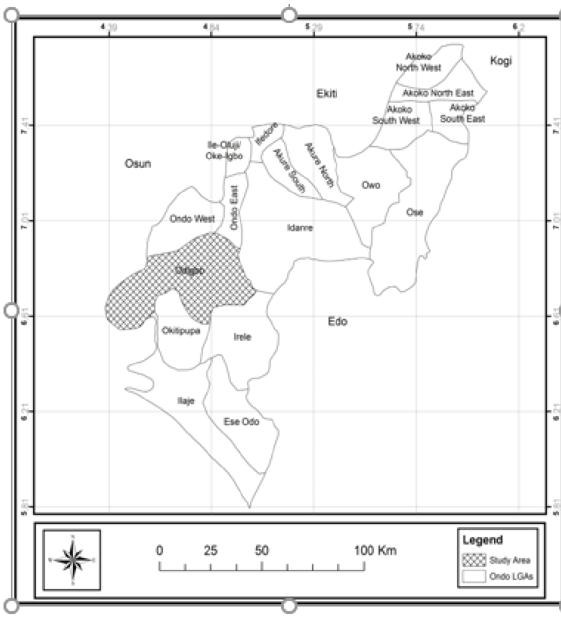

Fig 1: Map of Ondo State showing Odigbo Local Government Area (Author)

3.0 METHODOLOGY

The rubber stands of 6, 15 and 22 year old selected for this study were those identified within the plantation that were along sloping surfaces. The research design used for this study was basically experimental in nature to determine the possible effects of relief on soil physical and chemical properties and the relationship among the variables. Primary data was used for this study. Three rubber plots of varying ages were considered.

The objectives set for the study was a guide to selecting the rubber plots, hence selection was done by purposive sampling and mostly determined by plots available on sloping ground. The effect of slope on soil properties is most marked along transects running from the crest to the valley of a hill slope (Gerrand, 1981; Aweto & Enaruvbe, 2010). This provided the basis for field sampling. Three different sloping portions of rubber plantation of different ages were selected to ascertain the effects of slope on soil properties. The ages of the rubber plantations are:

(i) 6 years old rubber
(ii) 15 years old rubber plant
(iii) 22 years old rubber plant

The selection was based on the available rubber plantations on sloping areas in the study area. Also, an adjoining forest (F) in the same study area was used as a control for the study.

Transect of not more than 300m was run along four hill sloping areas each from the crest of the interfluve to the valley bottom. It was further divided into three slope segments – the upper, middle, and lower slope. Fifteen sample plots of 10m x 10m were delimited for study in each slope segment and five auger points within each of the quadrat were then randomly located for soil samples collection. Soil samples were collected randomly at five different points within the selected quadrat and they were bulked together. Soil samples were taken at the top layer of 0-15cm using a soil auger. Soil samples were analyzed for the following physical and chemical properties: Particle size composition by the hydrometer method (Bouyoucos, 1926), Soil organic matter by Walkley-Black method, Total nitrogen by Kjeldahl method (Bremner and Mulvaney, 1982)

Data analysis for the study relied on the use of descriptive analysis, and analysis of variance (ANOVA) statistical methods was used to make comparison and to determine the level of relationship between variables used in the study. Standard error bar chart was used to display the pattern of soil organic carbon and nitrogen components at the topsoil.

4.0 RESULT AND DISCUSSION

4.1: Soil physical properties with organic carbon and nitrogen content in the upper, middle and lower slopes under rubber plantation of varying ages.

Table 1: Mean Values of Soil Physical and Organic Carbon and Nitrogen in the 0 -15cm soil layer

Soil Properties	6YEAR RUBBER			15YEAR RUBBER			22YEAR RUBBER			FOREST		
	Upper	middle	lower	Upper	middle	lower	Upper	middle	lower	Upper	middle	lower
% Sand	75.84	52.10	56.44	70.16	74.13	69.28	62.08	67.52	67.04	79.80	83.80	79.80
% Silt	13.76	18.80	14.20	9.92	9.80	3.80	13.80	10.60	7.40	9.40	7.40	13.40
% Clay	10.40	29.10	29.36	19.92	16.07	26.92	24.12	21.88	25.56	10.80	8.80	6.80
OrganicC %	3.29	1.62	3.30	1.78	1.96	2.04	1.58	1.43	1.65	2.02	1.87	3.87
Total N %	0.79	0.39	0.80	0.43	0.48	0.49	0.38	0.35	0.40	0.49	0.45	0.80

4.1.1 Sand, Silt and Clay

Sand is the dominant inorganic fragment in all the segments of the slope studied. It accounts for a mean proportion of 52-83% (table 1) of the inorganic soil fragment with the higher value occurring in the upper slope positions when compared with clay and silt. From the mean values, clay tends to increase along the slope positions in all the rubber plots.

Multiple comparisons show a significant difference between the upper and lower slope positions of 6 and 15years rubber. From studies this might be because of slope which accelerated the movement of clay particles by runoff water and gravity. According to Esu, Akpan-Idiok & Eyong (2008) topography has a great influence on the pattern of soil distribution over landscape.

Multiple comparisons of mean differences show significant difference between the middle and lower slope positions of 6 and 15years rubber and between upper and lower positions of 22years rubber.

In 6 years rubber plot, clay content increased down the slope positions with 10.4% at the upper, 29.1% at the middle and 29.36% at the lower slope (table 1). In 15 years rubber plot, clay content varied with the highest value of 26.92% at the lower position while under 22years rubber, the highest clay content value of 25.56% was recorded at the lower slope position. ANOVA shows that significant difference exists along the slope segments under the rubber plots. In addition to this, multiple comparison using the Bonferroni method indicates a significant difference between the upper and lower slope positions under 22years rubber at $P<.05$. This difference could be attributed to the transportation of the fine particles down slope as observed by Khan *et al* (2013) that during erosional processes, suspended finer particles are transported down the slope where they accumulate, and this increased the clay content down slope.

According to Lawal *et al* (2014) surface erosion and depositional processes by runoff might have contributed to the differences observed in the textural differences along the slope positions under the rubber plantations. It is also of importance to note that though the soils are formed in the same climatic environment, different topographic positions account for the differences in textural composition.

4.1.2 Organic Carbon

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by the soil microbes as the decay occurs. Such material is continually being broken down and re-synthesized by soil micro- organisms. Organic matter in the soil is the estimation of humus present in the soil and it is a complex and varied mixture of organic substances. It provides much of the cat-ion exchange and water holding capacities of surface soils.

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Soil organic matter also contains large quantities of plant nutrients and acts as a slow-release nutrient storehouse especially for nitrogen.

The mean values of organic matter were significantly higher at the lower slope positions of all the rubber plots with 3.3% in 6years rubber, 2.04% in 15years rubber and 1.65% in 22 years rubber (table 1). Multiple comparison shows significant difference with upper slope segment having higher content than the middle slope as well between middle slope segment having lower content than the lower slope at P<.05 in 6years rubber. This could be due to deposition of transported organic matter from upper positions as observed by Taher and Gihan (2015). Also, soils in the lower slopes are saturated with water for a long period than those of the middle and upper slope positions and this inhibits bacterial decomposition of soil organic matter in the lower slope. Higher organic carbon under 22years rubber could also be due to more clayey soils at the lower slope (Yossif *et al*, 2015). More clayey soils generally tend to contain higher levels of organic matter mainly because of the tendency of clays to slow down microbial degradation of organic matter as clays form clay-humus complexes with organic matter (Aweto, 2010).

In this study, the organic matter content at the lower slope position was relatively higher mainly due to the higher input of organic matter from residues of plants transported downslope. In contrast, Brubaker *et al* (1993) in their study observed a decrease in organic matter and clay content at the lower slope segment.

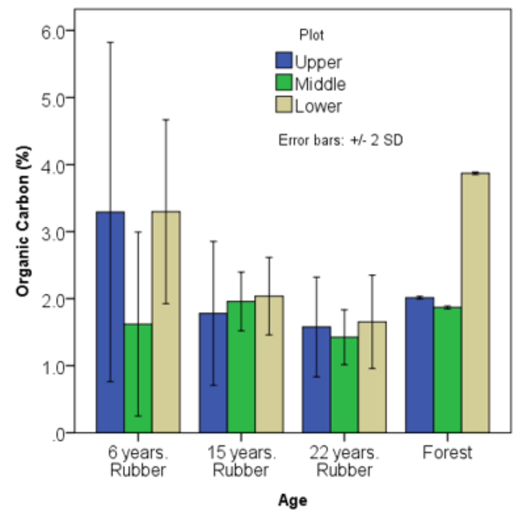

Fig 2: Organic carbon at different slope positions under rubber plantation of different ages (0-15cm)

4.1.3 Total Nitrogen

Nitrogen is important for plant growth and development and of the macro nutrients; it is often the one that is most limiting. Nitrogen in the soluble form is mobile in the soil and can be leached below the root zone of the crop. It can be transported off site in run off due to rain or irrigation which contributes to eutrophication of surface water due to excess growth of algae and micro-organisms. Nitrogen is an essential element for all growth processes in plants, if it is not available, the plant remains stunted and comparatively undeveloped (Brady and Weil, 2005).

ANOVA revealed significant difference in total nitrogen along the slope segments, multiple comparisons show significant differences at P<.05 between upper & middle, and middle & lower slope positions of 6 years rubber. Under 6 years rubber, nitrogen content was 0.80% at the lower slope position, 0.49% under 15 and 0.40% under 22 years rubber (fig 3a). All these values were higher when compared with those of upper and middle slope positions.

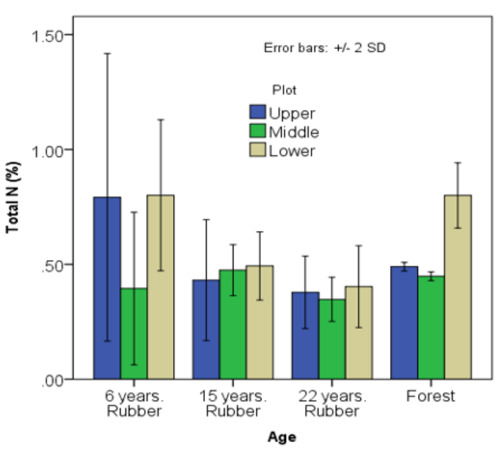

Fig 3: Nitrogen content at different slope positions under rubber plantation of different ages (0-15cm)

4. 2: Effect of slope position on the organic carbon of soil under rubber plantation of varying ages

Table 2a: Descriptive Statistics for Level of Organic Carbon(C) by Age of Rubber and Slope

Age of rubber	Upper			Medium			Lower		
	M	SD	N	M	SD	N	M	SD	N
Forest	2.02	.01	15	1.87	.01	15	3.87	.01	15
6 years	3.29	1.26	15	1.62	.69	15	3.30	.69	15
15years	1.78	.54	15	1.96	.22	15	2.04	.29	15
22years	1.58	.37	15	1.43	.21	15	1.65	.35	15

Table 2b: ANOVA Summary for Level of Organic Carbon(C) by Age of Rubber and Slope

Source	SS	Df	MS	F	Sig
Age	33.80	3.00	11.27	41.47	.000
Slope	8.99	2.00	4.49	16.54	.000
Age × Slope	20.17	6.00	3.36	12.37	.000
Error	45.64	168.00	.27		

$R^2 = .58$, Adjusted $R^2 = .55$

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A two- way ANOVA (Table 2b) with age of rubber (22years, 6 years, 15 years and forest) and slope (upper, middle and lower) showed significant main effects of age of rubber (F (3, 168) = 41.47, p = 0.0005, η^2=.43) and slope (F (2, 168) = 16.54, p = 0.0005, η^2=.16) in levels of organic carbon. This implies differences in the levels of organic carbon among the four levels of age of rubber plantation and the three levels of slope within the plantations. There was a statistically significant interaction between age of rubber and slope of the plantations in the levels of organic carbon (F (6, 168) = 12.37, p = 0.0005, η^2=.31), indicating the mean differences in organic carbon levels were caused by the effects of both age of rubber plantations and slope. Table 2b shows that the factors of age and slope in the ANOVA model together explained 55 percent of the variability in the levels of organic carbon. The beta square (η^2) which measures the effect size was large for all the factors. The effect size revealed that the factors of age, slope and 'age × slope' contributed 43%, 16% and 31% respectively to the variability in the dependent variable, organic carbon.

Comparing the mean values, organic carbon was highest at all the lower slope positions of the rubber plantations indicating the impact of slope position on the soil nutrient. Soil organic carbon transported from the upper and middle slope positions got deposited at the lower slope position thus the high content at the lower slope positions.

Objective 3: Effect of slope position on the Nitrogen content of soil under rubber plantation of varying ages

Table 3a: Descriptive Statistics for Level of Nitrogen (N) by Age of Rubber and Slope

	Slope								
	Upper			Medium			Low		
Age of rubber	M	SD	N	M	SD	N	M	SD	N
Forest	.49	.01	15	.45	.01	15	.80	.01	15
6 years	.79	.31	15	.39	.17	15	.80	.16	15
15 years	.43	.13	15	.48	.06	15	.49	.07	15
22 years	.38	.08	15	.35	.05	15	.40	.09	15

Table 3b: ANOVA Summary for Level of Nitrogen (N) by Age of Rubber and Slope

Source	SS	df	MS	F	Sig
Age	1.981	3	.660	40.59	.000
Slope	.518	2	.259	15.91	.000
Age × Slope	1.166	6	.194	11.95	.000
Error	2.733	168	.016		

R^2 = .57, Adjusted R^2 = .55

The levels of N_2 in rubber plantations of different ages and slopes are presented in Tables 3a and 3b. The results of a 4 x 3 ANOVA with age of rubber (22years, 6 years, 15 years and forest) and slope (upper, middle and lower) revealed a main effect of age of rubber ($F(3, 168) = 40.59$, $p = 0.0005$, $\eta^2=.42$) and slope ($F(2, 168) = 15.91$, $p = 0.0005$, $\eta^2=.16$). The estimated marginal means of age of rubber (22years, 6 years, 15 years and forest) revealed differences in nitrogen levels of 0.38, 0.66, 0.47 and 0.46 respectively. The estimated marginal means of slope of rubber plantations (upper, middle and lower) also showed differences in nitrogen levels of 0.52, 0.42 and 0.54 respectively. Table 3a showed that N_2 levels in rubber plantations of different ages depends on the different slope positions which was evident in the mean values along the slope positions.

There was a statistically significant interaction between age of rubber and slope, ($F(6, 168) = 11.95$, $p = 0.0005$, $\eta^2=.30$). This indicates that mean differences in N_2 levels were caused by both age of rubber plantations and slopes. Table 3b shows that the factors of age and slope in the ANOVA model together explained 55 percent of the variability in the levels of N_2. The eta square (η^2) which measures the effect size was large for all the factors. The effect size revealed that the factors of age, slope and 'age × slope' contributed 42%, 16% and 30% respectively to the variability in the dependent variable,

CONCLUSION AND RECOMMENDATION

The slope positions and age of the rubber plantations influenced the movement, distribution and accumulation of soil organic carbon and nitrogen along the slope positions leading to a variation along the topo-sequence in the study area. These factors are important influencing determinants of soil properties in an area, among others. There was significant difference for organic carbon and nitrogen studied along the slope positions and major differences were observed at the upper and lower slope positions. Soil properties vary all through the plots considered and the middle slope position also had some properties with high mean value.

In the light of this, the study therefore recommends that:

1. Soil survey should be conducted before plantation would take place to ascertain the suitability of the land.
2. Soil under rubber plantation at different slope positions should be managed differently based on the available nutrient at each slope position for optimum productivity taking cognizance of the upper and lower slope positions.
3. Management practices such as terracing and proper land leveling, if possible, should be

done to improve the effect of slope on soil properties.

4. With increasing age of rubber some nutrient decreased, which suggests that there may be decrease in rubber yield over time hence, there is need for the use of fertilizers to soils with increase in age of rubber for higher productivity.

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